MULTIMEDIA **UNIVERSITY**
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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2018/2019

EEL2216 – CONTROL THEORY
(All sections / Groups)

27 MAY 2019
9:00 AM – 11:00 AM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages (including this cover page) with 4 Questions only and an appendix.

2. Attempt **ALL** questions. The distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) A system has a transfer function, $H(s)$, and an input, $R(s)$, given by

$$H(s) = \frac{2s+5}{(s+2)(s+5)}\, ;\; R(s) = \frac{1}{s}.$$

    (i) What is the output response, $Y(s)$, of the system?   [2 marks]

    (ii) Using inverse Laplace transform, determine $y(t)$ assuming zero initial conditions.   [8 marks]

    (iii) Calculate the final value of $y(t)$ using the Final Value Theorem.   [2 marks]

(b) For the signal flow graph shown in Figure Q1, determine the transfer function $C(s)/R(s)$ using Mason's gain formula.   [13 marks]
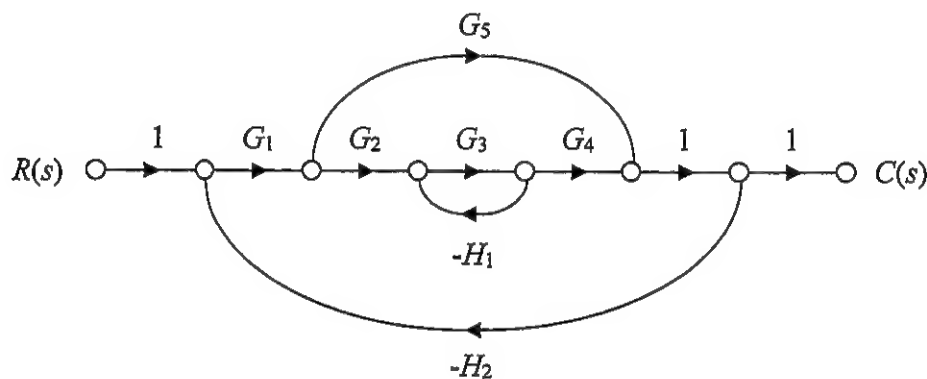

Figure Q1

Question 2

(a) The output response of a system is the sum of the transient response and the steady-state response. Explain the terms *transient response* and *steady-state response*.

[3 marks]

(b) The open loop transfer function of a unity feedback system is given by

$$G(s) = \frac{20}{s^5 + 2s^4 + 6s^3 + 5s^2 + 8s} .$$

    (i) Using the Routh-Hurwitz Criterion, determine the number of poles on the left-half, right-half and the imaginary axis of the *s*-plane, respectively.

[8 marks]

    (ii) Comment on the stability of the closed loop system.   [2 marks]

(c) Consider a unity feedback system with a loop transfer function

$$KG(s)H(s) = \frac{K(s+1)}{s(s+2)(s^2+5)} .$$

Determine the following:

    (i) The starting and ending points of the root locus.   [2 marks]

    (ii) Root loci on the real axis.   [2 marks]

    (iii) Behaviour at infinity.   [3 marks]

    (iv) Angle of departure.   [2 marks]

    (v) Sketch the root locus.   [3 marks]

Continued ...

Question 3

(a) Explain the definition of Nyquist stability criterion.   [4 marks]

(b) The open loop transfer function of a unity feedback system is given by
$$G(s) = \frac{k}{2s(s+2)(s+6)}.$$

   (i) Derive the equation for magnitude, $|G(j\omega)|$, and phase, $\angle G(j\omega)$. [2.5 marks]

   (ii) Sketch the Nyquist plot.   [6.5 marks]

   (iii) Identify the intersection point of the Nyquist plot on the real axis.

      (Hint: $\tan^{-1} A + \tan^{-1} B = \tan^{-1}\left(\dfrac{A+B}{1-AB}\right)$)   [6 marks]

   (iv) Based on the result in part(b)(iii), discuss the range of k for stability, instability, and marginal stability using Nyquist stability criterion.   [6 marks]

Question 4

(a) Draw the three-op-amp electronic circuit realisation of the proportional-integral (PI) controller. Obtain the proportional constant K_P and integral constant K_I in terms of the circuit components.   [12 marks]

(b) A process has transfer function given by
$$G_p(s) = \frac{1}{s(s+0.6)}.$$

Design a proportional-derivative (PD) controller so that the damping ratio of the closed loop system is $\zeta = 0.8$. The steady-state error for a unit ramp input should be 0.01.   [13 marks]

Continued ...

Appendix - Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\dfrac{1}{s}$
t	$\dfrac{1}{s^2}$
$\dfrac{t^{n-1}}{(n-1)!}$ $(n = 1, 2, 3, \ldots)$	$\dfrac{1}{s^n}$
t^n $(n = 1, 2, 3, \ldots)$	$\dfrac{n!}{s^{n+1}}$
e^{-at}	$\dfrac{1}{s+a}$
te^{-at}	$\dfrac{1}{(s+a)^2}$
$\dfrac{t^{n-1}}{(n-1)!}e^{-at}$ $(n = 1, 2, 3, \ldots)$	$\dfrac{1}{(s+a)^n}$
$t^n e^{-at}$ $(n = 1, 2, 3, \ldots)$	$\dfrac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\dfrac{\omega}{s^2 + \omega^2}$
$\cos \omega t$	$\dfrac{s}{s^2 + \omega^2}$
$\sinh \omega t$	$\dfrac{\omega}{s^2 - \omega^2}$
$\cosh \omega t$	$\dfrac{s}{s^2 - \omega^2}$
$\dfrac{1}{a}(1 - e^{-at})$	$\dfrac{1}{s(s+a)}$
$\dfrac{1}{b-a}(e^{-at} - e^{-bt})$	$\dfrac{1}{(s+a)(s+b)}$
$\dfrac{1}{b-a}(be^{-bt} - ae^{-at})$	$\dfrac{s}{(s+a)(s+b)}$
$\dfrac{1}{ab}\left[1 + \dfrac{1}{a-b}(be^{-at} - ae^{-bt})\right]$	$\dfrac{1}{s(s+a)(s+b)}$

Continued...

Appendix - Laplace Transform Pairs (continued)

$\dfrac{1}{a^2}(1 - e^{-at} - ate^{-at})$	$\dfrac{1}{s(s+a)^2}$
$\dfrac{1}{a^2}(at - 1 + e^{-at})$	$\dfrac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\dfrac{\omega}{(s+a)^2 + \omega^2}$
$e^{-at}\cos\omega t$	$\dfrac{s+a}{(s+a)^2 + \omega^2}$
$\dfrac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}\,t$	$\dfrac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$
$-\dfrac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t - \phi)$ $\phi = \tan^{-1}\dfrac{\sqrt{1-\zeta^2}}{\zeta}$	$\dfrac{s}{s^2 + 2\zeta\omega_n s + \omega_n^2}$
$1 - \dfrac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t + \phi)$ $\phi = \tan^{-1}\dfrac{\sqrt{1-\zeta^2}}{\zeta}$	$\dfrac{\omega_n^2}{s(s^2 + 2\zeta\omega_n s + \omega_n^2)}$
$1 - \cos\omega t$	$\dfrac{\omega^2}{s(s^2 + \omega^2)}$
$\omega t - \sin\omega t$	$\dfrac{\omega^3}{s^2(s^2 + \omega^2)}$
$\sin\omega t - \omega t\cos\omega t$	$\dfrac{2\omega^3}{(s^2 + \omega^2)^2}$
$\dfrac{1}{2\omega}t\sin\omega t$	$\dfrac{s}{(s^2 + \omega^2)^2}$
$t\cos\omega t$	$\dfrac{s^2 - \omega^2}{(s^2 + \omega^2)^2}$
$\dfrac{1}{\omega_2^2 - \omega_1^2}(\cos\omega_1 t - \cos\omega_2 t)\ \ (\omega_1^2 \neq \omega_2^2)$	$\dfrac{s}{(s^2 + \omega_1^2)(s^2 + \omega_2^2)}$
$\dfrac{1}{2\omega}(\sin\omega t + \omega t\cos\omega t)$	$\dfrac{s^2}{(s^2 + \omega^2)^2}$

End of Paper